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Success of EPA's Stratospheric Ozone Engineering Research

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16. ABSTRACT The paper summarizes recent successes in, as well as work in progress (with the cooperation of industry) on, EPA's stratospheric ozone engineering research. The Montreal Protocol and U.S. regulations implementing the Protocol necessitate that engineering solutions be found and implemented to avoid the use of certain chlorofluorocarbons (CFCs) and halons. CFCs and halons are used for solvents, refrigerants, aerosol propellants, foams, and fire protection. Nearly all EPA activities in this program involve pollution prevention as the first alternative. This includes alternative processes, alternative chemicals, alternative means of accomplishing the desired service, and recycling. Industry cooperation is needed in order to take advantage of industry's expertise, to get industry to buy into the solution, to conserve valuable time and resources, and to implement results rapidly. Since the problem will be solved only through international efforts, the U.S. is also placing high priority on technical assistance to developing countries.

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Ozone	Propellants	Stationary Sources	07B	21I
Stratosphere	Foam	Global Warming	04A	11G
Chlorohydrocarbons		Chlorofluorocarbons	07C	
Fluorohydrocarbons		Halons		
Solvents	Fire Protection		11K	13L
Refrigerants			13A	

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Success of EPA's Stratospheric Ozone Engineering Research

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INTRODUCTION

The Environmental Protection Agency (EPA) has been working for several years to protect stratospheric ozone against depletion from chlorofluorocarbons (CFCs) and halons. Events leading up to the Montreal Protocol[1], the Montreal Protocol itself, U.S. regulation[2] implementing the Protocol, and the Advance Notice of Proposed Rulemaking[3] all have helped shape the required response. EPA's Office of Air and Radiation and Office of Research and Development have effectively addressed the problem via cooperative efforts with industry, academia, and other government entities. Initial efforts along these lines have been fully successful, and additional cooperative efforts have been easily undertaken. Other papers in this session which provide more detail on aspects which are overviewed in this paper are: "Preliminary Selection of Refrigerants for Dual Circuit and Lorenz Refrigerator/Freezers," 90-138.2[4]; "Recycle and Disposal Options for CFCs and Halons," 90-138.4[5]; and "Reduction of CFC Usage in U.S. Exempted and Excluded Aerosols," 90-138.5[6].

The chemicals currently addressed by the Protocol and U.S. regulation are CFCs-11, -12, -113, 114, and -115 and halons-1211, -1301, and -2402. These are all fully halogenated carbon compounds. However, there are concerns regarding other sources of anthropogenic chemicals which release chlorine into the atmosphere (e.g., methyl chloroform and carbon tetrachloride) or release other chemicals which enter into reactions affecting the depletion of stratospheric ozone (e.g., methane and nitrous oxide). The Protocol requires that technical assessments be made at least every 4 years to determine whether changes should be made to the Protocol requirements. This June, use of methyl chloroform and carbon tetrachloride may be restricted, and a schedule may be established for the phaseout of CFCs and halons.

A phaseout of CFCs and halons and restriction of other ozone-depleting substances will require additional engineering research and development. However, the cooperative program that has been established gives us every reason to believe that we will be successful. We cannot afford not to be successful.

GLOBAL APPROACH

The program that has been described has referred to examples where the U.S. is involved with other countries. The stratospheric ozone problem is being solved by multilateral action. Developed countries around the world are devoting time and resources in cooperative approaches to solving the problem. Canada, the European Economic Community, and Scandinavian countries are all actively involved. Some of these have proposed and are enacting more ambitious phaseout schedules than are required by the Protocol. Perhaps one of the most encouraging signs is the attitude of some of the leading developing countries. Under the Protocol, developing countries are allowed to increase their use of Protocol compounds during the next 10 years. Due to their economic circumstances and need to increase their standards of living, one might expect them to take full advantage of this provision. However, leading developing countries are also reducing their use of ozone-depleting substances. They do desire that acceptable alternatives be made available to them with the necessary technical support so that they can achieve progress without harming the environment. The U.S. is working with several developing

countries including Brazil, Egypt, India, Mexico, and The Peoples Republic of China.

TECHNICAL PROGRESS AND NEEDS

The major uses of the Protocol chemicals are in refrigeration, foam, solvents, fire protection, and aerosols. Each of these can be further subdivided into many other categories such as was done in the Regulatory Impact Analysis where over 70 categories were discussed and evaluated. Therefore, a solution in a particular use may not be a solution for the entire major category. Nevertheless, industry either on its own or through government encouragement, has made significant progress in several areas of need. For the most part, this progress has been in the areas with the most profit potential or that were the easiest to solve.

Automobile Air-Conditioning

In automobile air-conditioning, a program has been completed that has seen EPA's Air and Energy Engineering Research Laboratory, in cooperation with the Mobile Air Conditioning Society, Motor Vehicle Manufacturers Association of the United States, Society of Automotive Engineers, and others, establish (through field sample gathering, in-house chemical analysis, data evaluation, and negotiation) a standard for recycled refrigerant for automotive use. EPA's participation provided both the fact and the appearance of unbiased data, a forum for agreement among diverse parties, and assurance to industry that EPA would accept the final results. The standard has been voluntarily accepted by the affected parties, and some equipment to meet the standards has been certified by Underwriters Laboratories. Additional equipment is being tested by them. For the long term, a replacement chemical or a nonchemical system without stratospheric ozone deplètion or global warming potential will be necessary.

Fire Protection

In fire protection, uses of halons had expanded in recent years partly because of their desirable characteristics and from aggressive marketing. Now the market is collapsing as customers turn away from halons to protect the stratospheric ozone layer. Recent evaluations have shown that, for most situations utilizing hand-held fire extinguishers, halons are not necessary. Chemicals such as water and carbon dioxide are equally effective. For total flooding fire protection systems, the criteria are different. In these systems, the agent becomes part of the atmosphere that is breathed by people. There are additional concerns for health effects since the agent is widely dispersed and any residue from its use should be as innocuous as feasible. Work remains to be done.

Solvents

In the U.S. and Canada, great progress is being made in the area of electronic circuit board cleaning and metal cleaning where the components are used for military purposes. A cooperative effort with industry, EPA, and the Department of Defense (DOD) is evaluating the various methods of cleaning that will achieve the level of cleanliness that is required for new ozone-safe alternatives. Also, industry has made good progress in collecting and

recycling solvent from cleaning operations. Technologies such as fluxless soldering obviating the need for cleaning, changing of materials of construction so that aqueous cleaning can be used, and other techniques are leading to reduced needs for CFCs in these operations. Chemical manufacturers also have tested new cleaning techniques based on chemicals such as HCFC-123 or -141b.

Rigid Polystyrene Foam

In the food packaging and food service areas, extruded polystyrene foam sheeting has been able to shift away from CFCs and is now using less harmful chemicals; e.g., HCFC-22 or blends of HCFC-22 with hydrocarbons, carbon dioxide, or nitrogen. This shift was accomplished with amazing speed including the necessary approvals from the Food and Drug Administration. The shift has been made without loss of product quality and without cost increase.

Chemical Detection

In order to enforce the import/export restrictions of the Protocol, methods are needed to detect whether a given product contains a Protocol compound or was made with a Protocol compound. Initial work was conducted on this problem for foam products. A technique was developed which involved melting a piece of the foam and allowing analysis to be conducted by a gas chromatograph with an electron capture detector. The test protocol was shared with Swedish scientists who have done further work in this area. Other products need to have techniques developed for their specific situations.

Chemical Transformation/Destruction

The Protocol would allow credit for destruction and transformation of Protocol compounds if done by acceptable means. The credit would permit a like amount of additional production of Protocol compounds. At present, the Protocol parties have not approved rules on the acceptability of any transformation or destruction technology. In the U.S., a proposed amendment to the final rule would require alteration of the molecular structure of the compound to be considered transformed. EPA has done a background study which indicated that the only commercially available method for destruction is thermal incineration. This study identified several potential problems due to unknown emissions. Such systems might result in products of incomplete combustion which could be quite harmful to people or the environment. Emission characterization of the thermal destruction techniques and evaluation and/or development of alternative techniques is needed.

Nitrous Oxide

Nitrous oxide is also a chemical that is involved in the balance of stratospheric ozone although it is not limited by the provisions of the Protocol at this time. This chemical has been increasing in the atmosphere at approximately 0.25 percent per year, and its source was believed to be fossil fuel combustion. Before determining what needed to be done, EPA conducted a series of workshops in cooperation with the Electric Power Research Institute (EPRI), Department of Energy, and others to determine what was known about the emissions of nitrous oxide from combustion sources as well as natural sources. This resulted in discovery of an anomaly in the data which cast doubt on

previous data which had indicated high levels of nitrous oxide in combustion stack emissions. EPA then conducted a crash program which went into the field to get on-line measurements which showed that a faulty sampling system had been used in almost all previous data collection around the world. Results of the crash program showed that, for one type of fossil fuel combustion, the combustor was not a significant source of nitrous oxide. Other combustion and noncombustion sources need to be evaluated.

Additional Areas

Additional engineering is needed including aerosols, foam, insulation, refrigeration, recycling of chemicals, fire protection, solvents, detection of chemicals in commerce, destruction and transformation of chemicals, and for other substances such as methyl chloroform, carbon tetrachloride, nitrous oxide, and methane.

ENGINEERING PROGRAM EMPHASIS

Refrigeration

EPA's largest effort involves home refrigerator/freezers since they are a large and globally growing use of CFCs, are large energy consumers, and little research and development was being conducted. Working with the Appliance Industry-Government CFC Replacement Consortium, Inc., EPA is evaluating the technical feasibility of changes to home refrigerator/freezers. One class of refrigerant being evaluated is the non-azeotropic refrigerant mixtures. These can be used with different components and configurations, one of which is known as the Lorenz cycle. This cycle allows separate evaporators in the freezer compartment and the fresh food compartment. This takes advantage of the changing temperature of evaporation of the non-azeotropic mixture which allows evaporation to take place at a higher temperature and pressure in the fresh food section requiring less compression energy. Other configurations are also being evaluated. These include two complete systems with their own compressors, evaporators, condensers, etc. for the freezer and fresh food sections separately. In addition to non-azeotropic refrigerant mixtures, ternary or other combinations may be evaluated.

EPA has utilized a computer model generated by the National Institute of Standards and Technology to predict performance of the refrigerants. From these evaluations, several refrigerants were selected for testing in modified refrigerator/freezers. Different combinations of refrigerants are being tested at several locations. These include U.S. universities, Oak Ridge National Laboratory, and a European university. Based on these results, the best refrigerant or refrigerants will be chosen for more extensive testing with improved hardware and different configurations. The goal of the program is to provide evidence that the systems have technical merit for reducing use of chemicals that contribute to stratospheric ozone depletion, improving energy efficiency, not releasing chemicals that might contribute to global climate warming, and providing reliable service. As these goals are achieved, EPA will continue to work with industry to support wide and rapid incorporation of the technology into production lines.

A related component of EPA's domestic refrigeration work is to meet the expressed desire of the developing countries for expanded refrigeration. Their needs differ from those of the U.S. and from each other. For example, one country has expressed the desire to have only fresh food refrigeration and not freezers. This requirement might suggest a different configuration and different refrigerant which will be far more energy efficient. EPA will be working with the developing countries to see that their needs are addressed, and that advances made in refrigeration technology are quickly made available to them.

Recycling

Recycling CFCs in the automotive area is already successful. Now the Alliance for Responsible CFC Policy has petitioned EPA to require recycling of all refrigerants on a national scale. Toward this end, EPA has initiated work to elucidate the CFC collection problems, types and quantities of contaminants, levels of acceptable impurities, servicing concerns, and labelling needs. The different types of refrigerants and specific uses complicate this problem compared to the automotive example.

Insulation

Insulation foams are a particular concern because they directly affect stratospheric ozone depletion and global climate change and indirectly affect global climate change through energy inefficiency and generation of carbon dioxide. EPA, in cooperation with the Department of Energy, the Polyisocyanurate Manufacturers Association, and others, is evaluating the use of HCFCs as the blowing agent for foam used as building insulation. The foams have been manufactured and are undergoing testing in a demonstration of energy efficiency and mechanical stability over time. EPA is also sponsoring research at the Massachusetts Institute of Technology to look at cell size optimization for foam systems to offset the loss of insulation value from a more thermally conductive blowing agent.

For appliance uses of insulation, a promising alternative is vacuum systems. These have no stratospheric ozone depletion or global warming potential. In fact, due to greatly increased insulation properties, vacuum systems would have a significant reduction in global warming compared to current systems. Several approaches have been proposed and need to be evaluated and further developed. These include both hard vacuum and soft vacuum systems with inherent differences in advantages and disadvantages.

Fire Protection

Fire protection involving total flooding systems in certain critical applications do not yet have alternatives to the halons. However, risks previously thought to require halons (such as protection for computer rooms) have alternatives available. For these, reconfiguration may be possible which would allow water to be used in certain parts of the facility. For example, a computer facility's fire probability might be highest in the electrical power source. Designs can be made that will isolate this source from the rest of the hardware. Therefore, one agent might be used in this area and another on the actual computer hardware where water or other agents might leave harmful residues. This type of approach would greatly lessen or eliminate the need

for halons.

For total flooding fire protection systems, alternative chemical agents are needed. Some progress is reported on this from industry but uncertainties remain. EPA is working with the Halons Alternatives Research Consortium which has defined a research program that starts with the fundamentals of fire extinguishment and progresses through development and testing of agents that would best meet the criteria for total flooding systems (i.e., halon-1301 alternative). The agents evaluated would range from those currently available, to near-term alternatives, to longer term chemicals that would be specifically designed to meet the criteria.

Aerosols

Some uses of Protocol chemicals have no acceptable substitute. In the late 1970s, most CFC uses in aerosols were eliminated. There are still some pharmaceutical uses where CFCs are considered essential. Some uses may be eliminated by replacing the CFCs with other similar but less harmful chemicals, some may go to completely different chemicals or different aerosol delivery systems, and others may go to alternative products that are not even aerosols.

Aerosol use is still prevalent in countries outside the U.S. About 30 percent of worldwide CFC use is in aerosols. EPA's experience from the 1970s can be especially valuable to countries still using CFC propelled aerosols. This is especially true for developing countries where existing use is already significant and expected to grow greatly. For this reason, EPA is working with developing countries to show them alternatives to CFCs and to transfer technology for manufacturing these products. These countries also have some experience that may be useful to others. For example, Mexico uses hydrocarbons as propellants but avoids many of the flammability and explosion problems with which we have to deal by taking advantage of their warmer climate. They use wall-less, outdoor filling "rooms" that are open to the weather as a natural dispersion, reducing costs and increasing safety.

New Alternative Chemicals

Since several areas of need might be best served in the long term by a new alternative chemical and at the suggestion of an industry work group, EPA and EPRI are working to determine properties of new chemicals that might find use in these applications. In most cases, the new chemicals do not exist and must be synthesized after which they are purified, properties determined, and then properties compared to criteria established for each end-use requirement. Should any of these prove to be worthy of further consideration, necessary data will be obtained with industry participation.

Nitrous Oxide

It is not clear to what extent nitrous oxide emissions contribute to concentrations of ozone in the stratosphere, but it is a known global warming gas. Although one type of fossil fuel combustor has been eliminated as a source of nitrous oxide, other types of fossil fuel combustors have not been evaluated. Some concern also exists with some of the newer technology that may see wide scale use in the future. Based on an EPA revised sampling

technique, combustion samples from around the world will be gathered and analyzed as a screening tool. For samples that show concern, more detailed testing will be conducted. Also, there is some suspicion that, after the combustion process, chemical reactions may take place which could still lead to formation of nitrous oxide in the plume. Should fossil fuel combustion be a problem, the first approach would be to evaluate prevention techniques such as combustion modification as a means of eliminating the problem.

Protocol Additions

If additional chemicals are added to the Protocol, EPA will need to be involved in finding and promoting similar solutions to the problems caused by their reduced use in commerce. For example, methyl chloroform is an excellent candidate for recycling similar to that being done with CFC solvents or refrigerants. In addition, alternative methods of accomplishing the same task that methyl chloroform now serves should be pursued.

SUMMARY

The U.S. solution to stratospheric ozone depletion is based on the Montreal Protocol. This involves U.S. regulation to implement the Protocol with the primary approach being via production quotas. The EPA program also recognizes that the best approach is one of pollution prevention and cooperation with industry. Almost all EPA activities in this program involve pollution prevention as the first alternative. This includes alternative processes, alternative chemicals, alternative means of accomplishing the desired service, and recycling. Industry cooperation is needed in order to take advantage of the expertise that industry has, to get industry to buy into the solution, to conserve valuable time and resources, and to be able to implement the results rapidly. Since the problem will be solved only through international efforts, the U.S. is also placing high priority on technical assistance to developing countries.

REFERENCES

1. Montreal Protocol on Substances that Deplete the Ozone Layer - Final Act, United Nations Environment Programme, 1987.

2. Protection of Stratospheric Ozone; Final Rule, U.S. Environmental Protection Agency, 40 CFR Part 82, Federal Register, August 12, 1988, pp 30566-30602.

3. Protection of Stratospheric Ozone; Advance Notice of Proposed Rulemaking, 40 CRF Part 82, Federal Register, August 12, 1988, pp 30604-30619.

4. Bare, Jane C., Preliminary Selection of Refrigerants for Dual Circuit and Lorenz Refrigerator/Freezers, 90-138.2, Presented at the 83rd Annual Meeting Air and Waste Management Association, Pittsburgh, PA, June 1990.

5. Harmon, Dale L., Rhodes, William J., Recycle and Disposal Options for CFCs and Halons, 90-138.4, Presented at the 83rd Annual Meeting Air and Waste Management Association, Pittsburgh, PA, June 1990.

6. Smith, N. Dean, Reduction of CFC Usage in U.S. Exempted and Excluded Aerosols, 90-138.5, Presented at the 83rd Annual Meeting Air and Waste Management Association, Pittsburgh, PA, June 1990.